ADDRESS

Delivered by the President on Presenting the Gold Medal of the Society to Mr. David Gill.

GENTLEMEN,—

I have now the pleasant duty to state to you the general grounds upon which your Council have felt justified in awarding the Society's Medal this year to Mr. David Gill, H.M. Astronomer at the Cape of Good Hope, for his Heliometric observations of *Mars* at Ascension, and discussion of his results.

The planet *Mars* has occupied no inconsiderable place in the successive attempts at the solution of the grand problem, the determination of the Earth's mean distance from the Sun, upon which depend all measures of absolute distances and dimensions beyond our Moon. The earliest real approximations to the value of the solar parallax were obtained, as is well known, in 1672, through the intervention of this planet, which, in the summer of that year, was at one of its close oppositions, and therefore most favourably situated for the object in view. The first of the Cassini's had perceived the advantage that might be taken of the near approach of *Mars* to the Earth to ascertain the amount of his parallax, and thence of the Sun's, by comparing observations made simultaneously, or nearly so, at distant points upon the Earth's surface; and, accordingly, when Richer was sent on an astronomical expedition to the island of Cayenne, in French Guiana, in 1672, it was arranged that observations of this planet should be specially made for comparison with others to be made at Paris. In Cassini's Memoir on this subject he refers to several methods of utilising observations of *Mars* for the determination of his parallax: one of which is now commonly known as the meridional method, while another corresponds in principle with that which we are accustomed to term the diurnal method. By the meridional method, or by comparisons of the meridional altitudes of *Mars* at Cayenne and Paris, he inferred that the solar parallax was $9\frac{1}{2}$ seconds, or, having regard to all the observations, that it might be taken indifferently from $9\frac{1}{2}$ seconds to $9\frac{2}{3}$ seconds.

It is gratifying to us as Englishmen that this important advance in the knowledge of the solar parallax from the exceptionally favourable Opposition of *Mars* in 1672 is not due alone to the French astronomer, but that our countryman Flamsteed arrived quite independently at nearly the same result. In the

history of his own life he tells that whilst he was inquiring for the planet's appulses to the fixed stars, by the help of Hecker's Ephemerides he found that in September 1672 the planet *Mars*, then newly past his perihelion and opposition to the Sun, would pass amongst three contiguous fixed stars in the water of *Aquarius*, and that, by reason he was then very near the Earth, this would be the most convenient opportunity that would be afforded for many years for determining his parallax, and consequently that of the Sun. A notice which he sent to Oldenburg was printed in No. 86 of the early "Transactions of the Royal Society," on August 19, 1672; and he further states that Oldenburg having before sent his admonition into France, the gentlemen of their Academy took care to have it observed in several places. But we have seen that there was independent action in France. Flamsteed nearly missed the opportunity of contributing to the knowledge of the Sun's distance, being called away from home on, as he says, the very day when he had designed to begin his observations; but he succeeded in observing *Mars* with the instruments of his friend Townley, and again on his return to Derby. These observations are found at pp. 15 and 16 of the first volume of the *Historia Cœlestis*: his conclusion therefrom was that the Sun's horizontal parallax could not be more than 10″.

On many occasions, as we all know, during the two centuries following, the planet *Mars* has been observed for the purpose of investigating the solar parallax, usually on the meridional method, without any result which could be properly called definite. Professor Harkness, of Washington, in a recent summary of results from various methods, gives as limiting values by observation of *Mars* on the meridional method 8″·84 and 8″·96, and on the diurnal method, 8″·60 and 8″·79. I have no intention of occupying your time by noticing in detail the successive attempts to measure the solar parallax through the intervention of *Mars*, but the first efforts of Flamsteed and Cassini will always possess exceptional interest.

Mr. Gill's investigation for which the Medal has been awarded forms part of the 46th volume of our *Memoirs*. He remarks that about a year after the last Transit of *Venus*, when observers began to compare notes, and attempts were made to select corresponding phases at the contacts, a doubt began to arise in the minds of many astronomers whether we should not again repeat the experience of the Transit in 1769, and find the observations capable of so many interpretations as almost to preclude the possibility of an unprejudiced and final discussion; and that in consequence his attention had been directed to the opportunity afforded by the close Opposition of *Mars* in September 1877, as a means of arriving at an independent determination of the solar parallax. In 1874, in conjunction with the present Earl of Crawford and Balcarres, he had attempted a new method of finding the solar parallax by combining the suggestions of Sir George Airy as to employing the diurnal method with those of Professor

Galle, with respect to utilising the minor planets, the Mauritius expedition allowing of the Heliometer being brought to bear upon the necessary observations. He was convinced that a very good determination of the parallax might be made by the diurnal method of extra-meridional transits and the high degree of precision which had been found to attend the Heliometric measures of the minor planet *Juno* at Mauritius in 1874 induced the anticipation that the employment of the same instrument in the case of *Mars* might lead to a more accurate result than any which would be likely to follow by the method of transits. Without supposing that the angular distance between a star and a disk like that of *Mars*, could be measured with the same precision as that between a star and such a stellar-looking object as a minor planet, he yet expected that a greater degree of precision would be attained than on any other known method of observation.

Under these circumstances Mr. Gill applied to the Earl of Crawford (then Lord Lindsay) for the loan of the Heliometer, with which he had had such satisfactory experience during the expedition organised by that nobleman for the observation of the last Transit of *Venus*, and his request, he tells us, met with a most ready compliance and the most effective assistance in carrying out the preparations for an expedition which Mr. Gill contemplated either to St. Helena or Ascension. In the autumn of 1876 application was made to the Government Grant Committee of the Royal Society, but some hesitation being felt as to voting the sum required to one object, however important, the Committee appear to have advised a reference to the Government, with the view to the expense being independently provided for. Here, however, the Council of the Royal Astronomical Society intervened, after receiving an application from Mr. Gill, and the requisite sum of 500*l.* was voted by the Council, three of the Fellows becoming security for the repayment of 250*l.* to the Society if that amount should not be obtained from some other source; and Mr. Gill has acknowledged his indebtedness to the scientific spirit and generous help in the last difficulties attending the organising of his expedition rendered by Lord Crawford, Dr. Warren de la Rue, and the President of the Royal Society.

Having decided to observe at Ascension (it is understood on the advice of Lieut. Neate, R.N.), Mr. Gill left England on June 15, 1877, and reached Ascension on July 13; no time was lost in erecting the Observatory, which was ready for work four days later. The instruments had all been landed without breakage or accident, mainly through the instructions issued by the chief proprietor of the line of mail steamships to his officers to afford every aid in the matter of transport; indeed, I shall, I believe, be divulging no secret when I add that the generous assistance rendered by Sir Donald Currie, M.P., in a scientific matter in which the Council of the Royal Astronomical Society had taken such active interest, called forth from them a cordial

vote of thanks to Sir Donald Currie on the occasion. The site originally fixed upon for the Observatory was changed for reasons which are fully detailed by Mr. Gill in his Memoir. A site at the south-west extremity of the island was ultimately selected, and on August 4 the Heliometer was in position in the new locality now called "Mars Bay." A single set of evening and morning observations of *Mars* during the night of July 31 had been obtained at the first site, and from August 4 to October 4 observations were continued at Mars Bay at every opportunity.

Mr. Gill left Ascension on January 9, and arrived in England on January 24.

In his investigation as it appears in the *Memoirs* many details were omitted, on the suggestion of the Council, from the original manuscript of the work, as possessing comparatively minor interest, but the Society is in possession of the original observations of *Mars* as they were forwarded from time to time from Ascension, and is also made the depository of the five volumes containing these original observations, where they will be available for future reference.

The Heliometer was fully described in vol. ii. of the Dun Echt Observatory publications. For determination of time Mr. Gill provided himself with a 30-inch transit instrument, which was mounted in a tent lent by the Admiralty from those used in the Transit of *Venus* expedition at Mokattam; with a Reflecting Circle by Troughton, and a Prismatic Circle by a Berlin optician. The methods of determining time are described, and the details of determination of latitude and longitude of the two Ascension stations are contained in Mr. Gill's original manuscript. In his reductions he uses the following, which he considers amply exact enough for the purposes in view:—

		h	m	s			°	′	″
Garrison, Ascension	Long.	0	57	42	W.	Lat.	−7	55	50
Mars Bay, Ascension		0	57	39	W.		−7	59	15

Before leaving England Mr. Gill had applied to the Directors of the principal Observatories in various parts of the world requesting meridian observations of the comparison stars intended to be employed in his observations of *Mars*. His application met with a most liberal response, fifteen series of observations in all having been received. The Observatories thus contributing to the success of the enterprise were those of Albany, U.S., Berlin, Cambridge, U.S., Cordoba, Greenwich, Königsberg, Leyden, Leipsic, Melbourne, Oxford, Paris, Pulkowa, and Washington.

The methods of observation with the Heliometer were very similar to those adopted in the case of the *Juno* observations at Mauritius, though some changes were made in one or two important points; the chief difference consisting in the use of a reversing prism placed in front of the eyepiece which could be rotated about its axis, by which "all the observations can be

made precisely as if the line joining all stars, or the planet and stars, had always a constant relation to the vertical axis of the observer's eye. This was always kept in mind, and all the measures were made with the prism so turned as to make the line joining the two objects under observation apparently horizontal. Other special precautions were adopted to ensure the utmost possible precision in the measures." Mr. Gill's Memoir enters into full particulars of instrumental adjustments, the formation of instrumental distances, corrections for refraction, &c.

An important and laborious part of the work consisted in the Heliometric triangulation of the comparison stars, with the view to adding additional precision to their meridian observation, according to the plan which Mr. Gill had notified in a communication on his proposed expedition presented to the Society in April 1877. Definitive mean and apparent places of the stars were deduced from a comparison of the results, proper motions where sensible being inferred from a discussion of all the old observations. Corrections to Right Ascensions depending upon magnitude were also investigated. Preliminary corrections to Leverrier's Tables of *Mars* were ascertained. Chapter XIII. of the Memoir contains the heliometric measures between July 31 and Oct. 3. The formation of the equations of condition is then explained, with reference to possible errors that may affect the comparison between an observed and tabular distance, including one—an effect of refraction—suggested to Mr. Gill by Sir George Airy. A table is given showing all the complete combinations that can be framed subject to conditions of strict symmetry in the morning and evening observations as well as regards identity of method in which the corresponding observations were made as in the arrangement of the equations. It is right to say that all important parts of the heavy calculations involved have been executed in duplicate. In Chapter XV. we have particulars as to the deduction of Mr. Gill's final results. The equations are treated upon two systems, by the method of least squares, the first and most laborious assigning for the Sun's parallax

$$8''\cdot78 \pm 0''\cdot012.$$

The second, involving a comparatively simple method of reduction, gave

$$8''\cdot784 \pm 0''\cdot013.$$

Mr. Gill concludes that whatever method of reduction be employed the result must be practically the same—viz., $8''\cdot78 \pm 0''\cdot012$, subject to a possible small correction due to sources of error, which he mentions.

This value for the solar parallax he presents as the definitive result of his investigations, and combining it with Listing's value of the equatorial radius, he infers for the mean distance of the

Earth from the Sun 93,080,000 miles. He concludes his Memoir with a comparison of results of the various methods of deducing the solar parallax, and reverts to an opinion he had long held, that perhaps the most promising method to ensure precision is by heliometric observation of the minor planets, or such of them as approach nearest to the Earth. He thinks that if a Heliometer of 6 or 7 inches aperture, in a portable form, were available, it might be conveyed from time to time, when exceptionally favourable oppositions of these bodies take place, to such stations as would be best situated for a particular opposition; and that "in this way, without undue loss of time, advantage might be taken of the most favourable opportunities, and in course of a few years such a series of determinations would be obtained as would set at rest this most important and difficult question."

I should remark that in what has preceded I have purposely confined myself to a brief outline of Mr. Gill's investigation, without touching upon any feature of it which can well be questioned by other astronomers; but in such discussions there will in most cases be some differences of opinion, especially in the formation and treatment of the equations of condition and deduction of probable error.

As a piece of admirable work, carried to its conclusion with the unremitting energy and great zeal which Mr. Gill has always evinced, I believe you will concur in the opinion of your Council that he has well deserved the award of the Medal.

My Lord Crawford,—In transmitting this Medal to Mr. Gill, I ask you to assure him of the high estimation with which the Royal Astronomical Society regards his energetic efforts in the cause of the science to which we are devoted, and to express our earnest wishes that continued health may enable him to apply them in the wide field which is open to him as H.M. Astronomer at the Cape, with equal discrimination and as great success as heretofore.